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Description

This invention relates to instruments for measuring concentrations of gas by ultrasonic wave and particularly to a gas-concentration measuring instrument capable of measuring the concentration of gas with high precision for a long continuous period of time by using a highly dampproof ultrasonic sensor.

There is known an instrument for measuring the concentration of a mixed gas or a single-component gas by utilizing the dependency of the propagation speed of ultrasonic wave on the concentration of gas to be measured as defined in the preambles of claims 1 and 4, and as disclosed in US-A-4,220,040. The principle of the measurement will first be described.

The propagation speed of ultrasonic wave in a mixture gas is determined by the constants, concentration and temperature of the mixture gas. In other words, the propagation speed can be expressed by the following equation (1):

$$v^2 = \sum_i C_{pi} X_i / \sum_i C_{vi} X_i \cdot 1 / \sum_i M_i X_i \cdot R \cdot T \quad \text{---------- (1)}$$

where

- v: propagation speed of ultrasonic wave in the mixture gas,
- C_{pi}: specific heat of the object gas i at constant pressure in the mixture gas,
- C_{vi}: specific heat at constant volume of the object gas i in the mixture gas,
- M_i: molecular weight of the object gas i in the mixture gas
- X_i: mole fraction of the object gas i of the mixture gas,
- R: gas constant, and
- T: absolute temperature of the mixture gas.

If the mixture gas is assumed to be comprised of air and carbon dioxide CO_2, Equation (1) is rewritten as

$$v^2 = (C_{pco_2} X_{co_2} + C_{pair} X_{air}) /$$

$$(C_{vco_2} X_{co2} + C_{vair} X_{air}) \cdot R \cdot T \quad \text{---- (2)}$$

The propagation speed of ultrasonic wave was calculated at each concentration of carbon dioxide CO_2 by substituting the constants and the absolute temperature, 293°K of the mixture gas into Equation (2). The results are shown in Table 1 and Fig 1.

Table 1

CO_2 (wt%)	0	20	40	60	80	100
Mole rate X_{CO_2}	0	0.141	0.305	0.503	0.725	1.00
v(m/sec)	343.07	329.66	315.56	300.30	285.04	268.25

Since $\Sigma X_i = 1$, Equation (2) is alternatively given as the following equation (3):

$$v^2 = \frac{[C_{pair} + (C_{pCO_2} - C_{pair})X_{CO_2}]}{[C_{vair} + (C_{vCO_2} - C_{vair})X_{CO_2}]} \times \frac{R \cdot T}{[M_{air} + (M_{CO_2} - M_{air})X_{CO_2}]} = G(X_2, T) \quad \text{-------} \quad (3)$$

Thus, the concentration

$$X_{CO_2}$$

is given as the following equation (4):

$$X_{CO_2} = F(v, T) \quad \text{----------} \quad (4)$$

In other words, the concentration of the object gas is the function of the propagation speed of ultrasonic wave v and the gas temperature T.

Fig. 2 shows a block diagram of a measuring system, designed on the basis of the above-mentioned theory.

Referring to Fig. 2, an ultrasonic sensor 1 includes a transmitting transducer 2 and receiving transducer 3 disposed opposedly to the transmitting transducer 2. This ultrasonic sensor 1 is mounted within an object gas atmosphere 4 by a proper method. The ultrasonic wave transmitted from transmitting transducer 2 is passed through the ultrasonic wave path 5 containing the object gas and received by the receiving transducer 3. The speed at which the ultrasonic wave passes through the ultrasonic wave path 5 is inversely proportional to the concentration of the object gas. The transmitting transducer 2 comprises an electrostrictive element. A drive amplifier 6 and a negative immitance converter 7 are used to amplify a high-frequency signal generated from a signal generator 8 that is controlled by a feedback oscillation amplifier 10 and to

improve the response characteristic. The receiving transducer 3 comprises an electrostrictive element. A preamplifier 9 is used to amplify the high-frequency signal from the receiving transducer 3 and supplies its output to the feedback oscillation amplifier 10. The resistor 11 and the negative immitance converter 12 are used to improve the response characteristic and the sensitivity of the receiving transducer 3.

On the other hand, the frequency, fm of the above-mentioned feedback oscillating system 13 has a relationship with the propagation speed v of the ultrasonic wave that passes through the path 5 within the object mixture gas, i.e., $f_m = k \cdot v/\ell$ (where ℓ is the distance between the transmitting transducer 2 and the receiving transducer 3 and k is a constant of proportionality). Thus, the frequency f_m of the feedback oscillating system 13 and the stable reference frequency f_o generated from the crystal oscillator element 14 are applied to the mixer 15 where the difference F between f_m and f_o is determined. This value F is converted into a voltage by the frequency-voltage converter 16 and supplied to the compensator 17.

A temperature sensor 18 comprises a thermistor, a temperature measuring resistor or a kind of thermocouple for measuring the temperature of the object gas atmosphere 4. The resulting temperature data is supplied to the compensator 17 for temperature by which the temperature dependency of the propagation speed of ultrasonic wave is eliminated. The temperature-compensated output voltage is indicated on the display unit 19 comprising an analog voltmeter, a digital voltmeter or a recorder.

An example of the measuring method of CO_2 gas concentration in a mixture gas comprising three components of air, carbon dioxide CO_2 and water vapor H_2O according to the present invention will be described in detail with reference to Figs. 2 and 3.

The gas cylinder 20 containing 100% CO_2 gas and a compressor-type air pump 21 respectively supply CO_2 gas and air to flow meters 22 and 23 with flow-adjusting valves by which the concentration of CO_2 gas is adjusted in advance. A mixing chamber 24 for mixing CO_2 gas and air is provided after the flow meters 22 and 23. The CO_2/air mixture gas from the mixing chamber 24 is introduced through a lead tube 26 into a measuring chamber 25. A water bath 27 sufficiently deep to immerse the lead tube is provided on the bottom of the measuring chamber 25. The CO_2/air mixture gas is blown off from gas blow-off holes provided appropriately in the lead tube 26 through the water bath 27 into the measuring chamber 25. By doing so, the relative humidity in the measuring chamber 25 increases to as high as 95 to 100%. On the upper region of the measuring chamber 25 there is provided a stirring fan 29 which is rotated by a motor 28. This stirring fan 29 serves to make the concentration of the mixture gas in the measuring chamber 25 uniform. The mixture gas is exhausted through a mixture gas outlet pipe 30 to the outside of the measuring chamber 25. The ultrasonic sensor 1 according to the present invention is disposed at an appropriate position in the measuring chamber 25, and connected by a shielded cable 31 to a computation control section 32 which includes the feedback oscillating system 13, the crystal oscillator element 14, the mixer 15, the frequency-voltage converter 16 and the compensator 17. The temperature-compensating temperature sensor 18 including a temperature-measuring resistor is connected through a cable 33 to the compensator 17 of the computation control section 32. The output voltage from the compensator 17 is set at 0 to 20 V against the CO_2 gas concentration of 0 to 20% by volume, so that the reading of the output voltage represents the concentration of the CO_2 gas. As the display unit 19, a digital voltmeter is used, and the frequency f_m of the feedback oscillating system 13 is monitored by a frequency counter 34. The mixture gas led out through the mixture gas outlet pipe 30 is introduced through an exhaust pipe 36 into an infrared gas analyzer 35 by which the CO_2 gas concentration is measured. In addition, a sampling port 37 for the gas chromatograph is provided on the way of the exhaust pipe 36, so that the CO_2 gas concentration is checked by the gas chromatograph.

A thermister temperature sensor 39 for measuring the temperature of the mixture gas is provided in the measuring chamber 25, which temperature is monitored by a temperature measuring instrument 40. The measuring chamber 25 is completely sealed except for the mixture gas inlet pipe 41 and the mixture gas outlet pipe 30. Moreover, the measuring chamber 25 is placed within a temperature-variable air constant-temperature over 42 which can be controlled to within ±0.1 °C in order that the temperature within the measuring chamber 25 can be arbitrarily changed.

Thus, on this ultrasonic gas concentration measuring instrument, CO_2 gas concentration values changed in the range of 0 to 20% by the flow meters 22 and 23 were actually measured for different temperatures of 27 °C, 35 °C and 42 °C within the measuring chamber 25, and the measured data from the infrared ray gas analyzer 35 and the gas chromatograph 38 are shown in Table 2 and Fig. 4.

Table 2

Temp. within chamber (°C)	Flow meter, set concentration (Vol%)	Gas chromatograph concentration (Vol%)	Ultrasonic concentration meter frequency *1 f_m (Hz)	Ultrasonic concentration meter concentration *2 (Vol%)	Infrared ray gas analyzer concentration (Vol%)
27.0	0	0	37.200	0	0
	5	5.58	36.752	5.6	5.6
	10	10.36	36.370	10.4	10.5
	14	14.14	36.075	14.1	14.1
	17	17.16	35.835	17.1	17.2
35.0	0	0	37.536	0	0
	4	4.07	37.205	4.1	4.2
	11	11.04	36.652	11.0	11.2
	12	12.48	36.535	12.5	12.8
	17	16.63	36.209	16.6	16.9
42.0	0	0	37.870	0	0
	3	3.37	37.596	3.4	3.4

- Cont'd -

Table 2 (Cont'd)

8	7.62	37.265	7.6	7.9
12	12.19	36.890	12.2	12.6
16	15.84	36.606	15.8	16.4

*1 Frequency of ultrasonic wave gas concentration measuring system.

*2 Reading on ultrasonic wave gas concentration measuring system.

From Table 2 and Fig. 4, it is seen that the frequency fm of the feedback oscillating system of the ultrasonic wave gas concentration measuring system according to the present invention represents a linear characteristic against the concentration indicated by the gas chromatograph and the infrared ray gas analyzer, and that the concentration indicated by the ultrasonic wave gas concentration measuring system is sufficiently identical to the concentration indicated by the gas chromatograph and the infrared ray gas

analyzer.

Although the foregoing description concerns an embodiment of the method and system for measuring the gas concentration including the three gas component of CO_2, air and H_2O, the present invention is not limited to such a composition of the mixture gas.

The ultrasonic sensors will hereinafter be described which are respectively used in the ultrasonic-wave transmitting element and the ultrasonic-wave receiving element of the ultrasonic wave gas concentration measuring system. The sensors including the elements have the same structure as that of the conventional one. That is, the sensor of this structure is formed by an ultrasonic transducer (for example, piezo-electric ceramic such as PZT) having silver electrodes fused together and which is attached to a plate or holder (made of, for example, metal or plastics). This type of ultrasonic sensor has so far been used for transmission or reception of ultrasonic wave in the measure/control ultrasonic equipment. This type of sensor has a drawback that the electrodes on the surface of the PZT or the like, for example, silver electrodes are easy to be electrically corroded in the presence of water vapor, thus often making it difficult to correctly convert an ultrasonic-wave signal to an electric signal and vice versa. Thus, in order to prevent the electrodes on the ultrasonic transducer from being electrically corroded, a sealing material such as silicone resin, epoxy resin or polyurethane has been utilized for preventing water vapor from entering into the holder. Nevertheless, even the ultrasonic sensor with its ultrasonic transducer attached to the holder and sealed with a sealing material was erroded by gradual intrusion of water vapor after it was continuously operated for as long a time as one to ten years in the atmosphere of 80 to 100% humidity. There is another countermeasure against the electric corrosion which employs a metal holder and seals it by welding. However, the adhesive resin with which the ultrasonic transducer is attached to the metal holder is easy to be deteriorated by heat upon welding.

The prior art will be described in more detail with reference to the accompanying drawings. Fig. 8 shows an example of the conventional ultrasonic sensor. Fig. 8a is a cross-sectional view of an ultrasonic sensor 59 and Fig. 8b is an enlarged cross-sectional view of an ultrasonic transducer 45 (made of, for example, a piezo-electric ceramic material such as PZT, or a resin material having a piezo-electric characteristic) and its peripheral portion.

As shown in Fig. 8b, the ultrasonic transducer 45 is attached with electrodes 60 and 61 and bonded to a holder 44 (made of for example, metal or resin) with an adhesive agent 62 having a good characteristic for propagation of the ultrasonic wave. The electrodes 60 and 61 are connected through wires 46 and 47 to terminals 48 and 49 which are fastened to a base 50 (made of for example, phenol resin laminated board or epoxy laminated board) as shown in Figs. 8a and 8b. The holder 44 is sealed by covering the base with a sealing material 51. This structure, however, has a drawback that when it is continuously operated for as long a time as, for example, one year to 10 years in the atmosphere including water vapor, water vapor enters into the holder 44 through the sealing material 51, making the electrodes 60 and 61 be electrically corroded so that the ultrasonic wave cannot be correctly transmitted and received.

Prior art document US-A-3 855 847 discloses an acoustic emission transducer comprising a tubular housing containing a piezoelectric element provided on its bottom, a positive electrode thereon and a ceramic potting compound poured to seal them. Its potting surface is formed in porous structure. A silicone like seal is provided on the surface in order to prevent invasion of moisture and/or oxygen.

It is an object of this invention to provide a gas concentration measuring instrument having an ultrasonic sensor used for the elements transmitting and receiving an ultrasonic wave, and which is capable of precisely measuring gas concentration continuously for a long time by forming on the ultrasonic sensor surface a thin film against the effect of water vapor.

To solve this object the present invention provides a gas measuring instrument as specified in claim 1.

A gas concentration measuring system uses a dampproof-type ultrasonic sensor which basically comprises an ultrasonic transducer, a holder and a sealing material and which is characterized in that a film of an electrically conductive material and/or an electrically, non-conductive material is formed on the surface of the sealing material.

A thin film is formed on the sealing material of a conventional ultrasonic sensor, thereby greatly increasing the moisture resistance of the conventional ultrasonic sensor. Thus, the ultrasonic sensor used in the ultrasonic gas concentration measuring instrument can be continuously operated for a long period of time in the atmosphere including water vapor. An accelerated test was made on the ultrasonic sensor with the thin film formed, to be used in the present invention and the conventional ultrasonic sensor, and the results are shown in Figs 10. In this test, each ultrasonic sensor was immersed in 60 • C warm water and applied with a DC voltage. In Fig. 10, the ordinate, 66 indicates the insulating resistance expressed in megohms MΩ and the abscissa, 65 is the time for which the test was made. From the comparison between a curve 63 for the ultrasonic sensor with thin film to be used in the present invention and a curve 64 for the

conventional ultrasonic sensor in Fig. 10, it will be understood that the sensor to be used in the present invention has no change of its insulating resistance, or is excellent in its moisture resistance. Moreover, the ultrasonic sensor or shown in Figs. 5 to 7 is embeded in the block 67 and a thin film is formed on the elastic sealing material 75, block 67 and vibrating and surface 71, thereby enabling its moisture resistance to be further increased.

Therefore, the ultrasonic gas concentration measuring instrument using the ultrasonic sensor of which the moisture resistance is greatly increased is almost not affected by the change of temperature and moisture and can precisely measure gas concentration continuously for a long period of times under high-humidity atmosphere. This feature is extremly useful for industry.

This invention can be more fully understood from the following detailed description when taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a graph showing a relation between CO_2 gas concentration and propagation speed of ultrasonic wave;

Fig. 2 is a block diagram of an example of the measuring system;

Fig. 3 shows one example of the method for measuring CO_2 gas concentration on a gas concentration measuring system;

Fig. 4 graphically represents the data of Table 2;

Figs. 5 to 7 are cross sectional views of examples of the ultrasonic sensor to be used in this invention;

Fig. 8a is a cross-sectional view of a conventional ultrasonic sensor;

Fig. 8b is an enlarged cross-sectional view of the ultrasonic transducer 45 and its peripheral portion of the sensor of Fig. 8a;

Fig. 9 is a cross-sectional view of an example of the ultrasonic wave sensor to be used in this invention; and

Fig. 10 is a graph showing the results of the dampproof test of the conventional sensor and the sensor to be used in this invention.

The present invention will be described with reference to the accompanying drawings.

Figs. 5 to 7 are cross-sectional side views of the ultrasonic sensors 43, 53 and 56 to be used in this invention. The basic structure of each sensor is the same as that of the conventional ultrasonic sensor shown in Fig. 8. The ultrasonic transducer 45 is provided with the electrodes 60 and 61 and attached to the holder 44 with the adhesive 62 as shown in Fig. 8b. The electrodes 60 and 61 are connected through the wires 46 and 47 to the terminals 48 and 49. The terminals 48 and 49 are fixed to the base 50 over which the sealing material 51 is covered to seal the holder 44.

Fig. 5 shows an ultrasonic sensor 43 with a thin film 52 formed on the surface of the sealing material 51. The material for the thin film 52 may be a nonconductive material, particularly SiO, SiO_2 or a fluorine-based resin such as polytetorafluoroethylene which can be deposited to be thin by for example, vacuum evaporation, sputtering, or ion plating. The thickness of the film should be in the range from 50nm (500Å), preferably from 150nm to 300nm (1500Å to 3000Å). Since the thin film 52 is non-conductive the portions of the terminals 48 and 49 which are projected through the sealing material 51 out of the holder 44 must be covered by, for example, Teflon (trade name) tape or the like in order that the thin film 52 is not deposited thereon except the surface of the sealing material 51.

Fig. 6 shows an ultrasonic sensor 53 with insulating films 54 and 55 formed on the terminals 48 and 49 which otherwise would be made in contact with the thin film 57 which is formed on the surface of the sealing material 51. The material for the thin film 57 must be an electrically conductive material which can be formed by, for example, vacuum evaporation, sputtering or ion plating, particularly Aℓ, An, Pb, Cu, titanium alloy, Ni, Cr, MoS_2, or MgF_2. The thickness of the film is in the range from 50nm to 500nm (500Å to 5000Å), preferably, from 150nm to 300nm (1500Å to 3000Å). Since the thin film 57 is electrically conductive, the insulating films 54 and 55 are formed on the areas of the terminals 48 and 49 which otherwise would be made in contact with the base 50 sealing material 51 and thin film 57. The portions of the terminals 48 and 49 which are projected through the sealing material 51 out of the holder 44 must be covered by, for example, Teflon (trade name) tape or the like in order that the thin film 57 is not deposited thereon except the surface of the sealing material 51.

Fig. 7 shows an ultrasonic sensor 56 with a thin film 58 formed on the surface of the sealing material 51 and on the areas of the surfaces of the terminals 48 and 49 which otherwise would be made in contact with the thin film 57 formed on the thin film 58. The material of the thin film 58 must be any insulating material which can be formed by vacuum evaporation, sputtering, or ion plating, particularly preferably an insulating material having coefficient of linear expansion between those of the sealing material 51 and thin film 57. The thickness of the thin film 58 is in the range from 10nm to 400nm (100Å to 4000Å), preferably 50nm to 100nm (500Å to 1000Å). Also, when the thin films 58 and 57 are formed, the portions of the terminals 48

and 49 which are projected through the sealing material 51 out of the holder 44 are covered by, for example, Teflon (trade name) tape in order that thin film 58 cannot be deposited thereon except the areas of the surfaces of the terminals 48 and 49 which otherwise would be made in contact with the thin film 57, and that the thin film 57 cannot be deposited thereon except part of the thin film 58 formed on the areas of the surfaces of the terminals 48 and 49.

The materials of the ultrasonic transducer 45, holder 44, base 50 and sealing material 51 for the sensor to be used in the present invention may be the same as those for the conventional sensor. That is, the material for the ultrasonic transducer may be a piezo-electric ceramic material such as PZT, a resin having a piezo-electric characteristic, the material for the holder may be any metal or plastic material, the material for the base may be a laminated board of phenol resin, epoxy resin or the like, and the sealing material may be silicone resin, epoxy resin, polyurethane or the like.

Fig. 9 shows an ultrasonic sensor 68 embedded in a block 67, this sensor being the same as mentioned with reference to Figs. 5 to 7. This block can improve the dampproof. The block 67 shown in Fig. 9 is made of a corrosion-resisting metal such as aluminum or stainless steel or a synthetic resin. An end surface 69 of the ultrasonic sensor 68 on the terminals 48, 49 side is set in position by a sensor supporting portion 70 of the block 67 so that a vibration end surface 71 of the ultrasonic sensor 68 is substantially flush with a block end surface 72 of the block 67. In an annular gap 73 between the ultrasonic sensor 62 and the block 67 is inserted elastic sealing materials 74 and 75 such as silicone resin or rubber which can absorb the ultrasonic vibration of the ultrasonic sensor 68, thereby fixing the ultrasonic sensor 68 to the block 67. A cable 76 is a two-core cable for transmission and reception of a high-frequency signal for ultrasonic wave to and from the terminals 48 and 49 of the ultrasonic sensor 68. This cable 76 is connected to the terminals 48 and 49 through an aperture 77 bored in the block 67 on the left end surface. The gap between the block 67 and the cable 76 is filled for sealing with a screw bush or a high moisture-resistant resin such as polybutadiene polyvinylidene chloride.

A thin film 78 and/or a thin film 79 are formed on the surface of the elastic sealing material 75, the vibrating end surface 71 and the block end surface 72 which otherwise would be exposed to the open air. The material for the thin film 78 must have a high adhesion to the elastic sealing material 75. For example, when the elastic sealing material 75 is a silicone resin, it must be formed by vacuum evaporation, sputtering, ion plating or the like and it is preferably a nonconductive thin film of SiO, SiO_2 or the like. The material for the thin film 79 is necessary to have a good adhesion to the thin film 78 of SiO, SiO_2 or the like, the block 67 and the vibration end surface 71, to be formed by vacuum evaporation, sputtering, ion plating or the like and to cause few pinholes in itself. Particularly, the material for this thin film 79 should be preferably a conductive thin film such as Al, Au, Pb, Cu, titanium alloy, Ni, Cr, MoS_2 or MgF_2. The thickness of the thin film 78 is in the range from 10nm to 400nm (100Å to 4000Å), preferably from 50nm to 100nm (500Å to 1000Å). The thickness of thin film 79 is in the range from 50nm to 500nm (500Å to 5000Å), preferably from 150nm to 300nm (1500Å to 3000Å). The total thickness of the thin films 78 and 79 is in the range from 100nm to 500nm (1000Å to 5000Å), preferably from 200nm to 400nm (2000Å to 4000Å).

While in this embodiment, two thin films 78 and 79 are formed, either of the films 78 or 79 may be formed depending on the combination of the materials of the elastic sealing material 75, block 67 and vibration end surface 71.

Claims

1. A gas concentration measuring instrument comprising:
   -- a feedback oscillating system (13) including:
   - an ultrasonic sensor (1) including an atmosphere of an object gas, an ultrasonic-wave transmitting element (2) and an ultrasonic-wave object gas atmosphere; wherein:
   - said transmitting element (2) is connected via a first negative immitance converter (7) to feedback amplifier means (9, 10) and is formed of an electrostrictive transducer for converting the applied high frequency signal to an ultrasonic wave and transmitting the same through the gas atmosphere to the receiving element (3),
   - said receiving element (3) is formed of an electrostrictive transducer for converting the transmitted ultrasonic wave to an electrical signal of an equal frequency with that of the ultrasonic wave and applying the signal of the equal frequency through a parallel circuit of a resistor (11) and a second negative immitance converter (12) to the feedback amplifier means (9, 10), and
   - the feedback amplifier means (9, 10) amplifies the applied frequency signal to control a signal generator (8); and

-- a computation output system including a mixer (15) for producing the difference between a frequency from the feedback oscillating system (13) and a reference frequency from a crystal oscillator (14), a frequency-voltage converter (16) for converting the difference frequency from said mixer (15) to a voltage and a compensator (17) for calculating a gas concentration from the output from said frequency-voltage converter (16) and the temperature information of the object gas atmosphere detected by a temperature sensor (18);

characterized in that

-- each of the transmitter element (2) and the receiving element (3) of said ultrasonic sensor (1) is of dampproof transducer structure (43, 53, 56, 68) formed fundamentally by a holder housing (44) defining an inner space between a bottom plate and an opposite opening, an ultrasonic vibrator of a piezoelectric element (45) disposed on the bottom plate and in the inner space, a base plate (50) closing the housing opening and attached with terminals (48 and 49), a sealing material layer (51) of resin poured and hardened on the base plate (50) for sealing the inner space and the vibrator against moisture penetration, and a thin dampproof film (52, 57, 58) of an electrically conductive material or an electrically nonconductive material formed by method of evaporation, sputtering or ion plating to cover outside surface of the sealing material layer (51) opposite to the base plate (50) (Fig. 5, 6).

2. A gas concentration measuring instrument according to claim 1, characterized in that said film deposited on the sealing material of the ultrasonic sensor is formed by a film (58) of a nonconductive material deposited on the sealing material layer (51) and a film (57) of a conductive material deposited on said nonconductive material film (58) (Fig. 7).

3. A gas concentration measuring instrument according to claim 2, characterized in that said ultrasonic sensor is embedded in a block, (67) defining an inner space containing said ultrasonic sensor, elastic sealing materials (74, 75) provided in air gaps between the block (67) and the sensor side surfaces to fix the ultrasonic sensor in place, and at least one of a film (78) of an electrically nonconductive material and a film (79) of an electrically conductive material formed by method of evaporation, sputtering or ion plating in order to cover an ultrasonic sensor vibrating end surface (71), block end surface (72) and elastic sealing material surface (Fig. 9).

Patentansprüche

1. Gerät zur Messung einer Gaskonzentration, welches umfaßt:
   -- ein Rückkopplungsoszillationssystem (13), welches beinhaltet:
      - einen Ultraschallsensor (1), der eine Atmosphäre eines Objektgases, ein Ultraschallwellen aussendendes Element (2) und eine Ultraschallwellen-Objektgasatmosphäre beinhaltet; wobei:
      - das aussendende Element (2) über einen ersten negativen Immittanzkonverter (7) mit einer Rückkopplungs-Verstärkereinrichtung (9, 10) verbunden ist und aus einem elektrostriktiven Meßgrößenumformer zum Konvertieren des angelegten Hochfrequenzsignals in eine Ultraschallwelle und zum Aussenden derselben durch die Gasatmosphäre zu einem Empfangselement (3) gebildet ist, wobei
      - das Empfangselement (3) aus einem elektrostriktiven Meßgrößenumformer zum Konvertieren der ausgesendeten Ultraschallwelle in ein elektrisches Signal mit einer Frequenz, die gleich der der Ultraschallwelle ist, und zum Anlegen des Signals der gleichen Frequenz durch eine Parallelschaltung aus einem Widerstand (11) und einem zweiten negativen Immittanz-Konverter (12) an die Rückkopplungs-Verstärkereinrichtung (9, 10) gebildet ist, und
      - die Rückkopplungs-Verstärkereinrichtung (9, 10) das angelegte Frequenzsignal verstärkt, um einen Signalgenerator (8) zu steuern; und
   -- ein Berechnungsausgangssystem, welches einen Mischer (15) zum Erzeugen der Differenz zwischen einer Frequenz von dem Rückkopplungsoszillationssystem (13) und einer Referenzfrequenz von einem Kristall- bzw. Quarzoszillator (14), einen Frequenz-Spannungs-Konverter (16) zum Konvertieren der Differenzfrequenz von dem Mischer (15) in eine Spannung und einen Kompensator (17) zum Berechnen einer Gaskonzentration aus dem Ausgang des Frequenz-Spannungs-Konverters (16) und der Temperaturinformation der objektgasatmosphäre, welche durch einen Temperatursensor (18) detektiert wird, beinhaltet,
   dadurch gekennzeichnet, daß

-- sowohl das Sendeelement (2) als auch das Empfangselement (3) des Ultraschallsensors (1) aus einer feuchtigkeitsbeständigen Meßgrößenumformer-Struktur (43, 53, 56, 68) gebildet ist, welche grundsätzlich durch ein Halterungsgehäuse (44), das einen Innenzwischenraum zwischen einer Grundplatte und einer gegenüberliegenden öffnung definiert, einen Ultraschallvibrator aus einem piezoelektrischen Element (45), das auf der Grundplatte und in dem Innenzwischenraum angeordnet ist, eine Basisplatte (50), welche die Gehäuseöffnung schließt und mit Anschlüssen (48, 49) befestigt ist, eine Versiegelungsmaterialschicht (51) aus Harz, welche auf die Basisplatte (50) gegossen und ausgehärtet ist, um den Innenzwischenraum und den Vibrator gegen das Eindringen von Feuchtigkeit zu versiegeln, und einen dünnen feuchtigkeitsbeständigen Film (52, 57, 58) aus einem elektrisch leitfähigen Material oder einem elektrisch nichtleitfähigem Material, welches durch ein Verfahren der Verdampfung, des Sputterns oder des Ionen-Plattierens ausgeformt ist, um die Außenoberfläche der Versiegelungsmaterialschicht (21), die der Basisplatte (50) gegenüberliegt, zu bedecken, gebildet ist (Fig. 5, 6).

2. Gerät zur Messung der Gaskonzentration nach Anspruch 1, dadurch gekennzeichnet, daß der Film, der auf dem Versiegelungsmaterial des Ultraschallsensors abgelagert ist, durch einen Film (58) aus einem nichtleitfähigen Material, welches auf der Versiegelungsmaterialschicht (51) abgelagert ist, und einen Film (57) aus einem leitfähigen Material, das auf dem nichtleitfähigen Materialfilm (58) abgelagert ist, gebildet ist (Fig. 7).

3. Gerät zur Messung der Gaskonzentration nach Anspruch 2, dadurch gekennzeichnet, daß der Ultraschallsensor in einen Block (67), der einen Innenzwischenraum definiert, der den Ultraschallsensor enthält, wobei elastische Versiegelungsmaterialien (75, 75) in Luftspalten zwischen dem Block (67) und den Sensorseitenflächen vorgesehen sind, um den Ultraschallsensor am Ort zu fixieren, und wenigstens einen Film (78) von einem Film aus einem elektrisch nichtleitfähigen Material und einem Film (79) aus einem elektrisch leitfähigen Material, der durch ein Verfahren der Verdampfung, des Sputterns oder des Ionenplattierens ausgeformt ist, um eine Ultraschallsensor-Vibrationsendoberfläche (71), eine Blockendeoberfläche (72) und eine elastische Versiegelungsmaterialoberfläche zu bedecken, eingebettet ist (Fig. 9).

Revendications

1. Un instrument pour mesurer la concentration d'un gaz, comportant :
   -- un système oscillant de réaction (13) comprenant :
      - un détecteur ultrasonique (1) comportant une atmosphère d'un gaz objet, un élément (2) émettant des ondes ultrasoniques et une atmosphère de gaz objet soumis à des ondes ultrasoniques ; dans lequel :
      - ledit élément émetteur (2) est relié par l'intermédiaire d'un premier convertisseur d'immitance négative à des moyens amplificateurs de réaction (9,10) et est formé d'un transducteur électrostrictif pour convertir le signal de fréquence élevée appliqué en une onde ultrasonique et émettre celle-ci vers l'élément récepteur (3) à travers l'atmosphère de gaz,
      - ledit élément récepteur (3) est formé d'un transducteur électrostrictif pour convertir l'onde ultrasonique émise en un signal électrique d'une fréquence égale à celle de l'onde ultrasonique et pour appliquer le signal de fréquence égale auxdits moyens amplificateurs de réaction (9,10) à travers un circuit parallèle d'une résistance (11) et d'un second convertisseur d'immitance négative, et
      - les moyens amplificateurs de réaction (9,10, amplifient le signal de fréquence appliqué pour commander un générateur de signal (8) ; et
   -- un système de sortie de calcul comportant un mélangeur (15) pour produire la différence entre la fréquence provenant du système oscillant de réaction (13) et une fréquence de référence provenant d'un oscillateur à cristal (14), un convertisseur fréquence - tension (16) pour convertir la fréquence de différence provenant dudit mélangeur (15) en une tension, et un compensateur (17) pour calculer une concentration de gaz à partir de la sortie provenant dudit convertisseur fréquence-tension (16) et de l'information de température de l'atmosphère du gaz objet détectée par un détecteur de température (18) ;
   caractérisé en ce que
   -- chacun de l'élément émetteur (2) et de l'élément récepteur (3) dudit détecteur ultrasonique (1) est une structure de transducteur (43,53,56,68) à l'abri de l'humidité formée fondamentalement par une

enveloppe de support (44) définissant un espace intérieur entre une plaque de fond et une ouverture opposée, un vibrateur ultrasonique d'un élément piézoélectrique (45) disposé sur la plaque de fond et dans l'espace intérieur, une plaque de base (50) fermant l'ouverture de l'enveloppe et liée à des bornes (48 et 49), une couche (51) de matière d'étanchéité en résine versée et durcie sur la plaque de base (50) pour assurer l'étanchéité de l'espace intérieur et du vibrateur contre la pénétration de l'humidité, et une fine pellicule (52,57,58) étanche à l'humidité en une matière électriquement conductrice ou en une matière électriquement non conductrice formée par la méthode d'évaporation, de pulvérisation ou de placage ionique pour couvrir la surface extérieure de la couche (51) de matière d'étanchéité opposée à la plaque de base (50) (Figs. 5,6).

2. Un instrument pour mesurer la concentration d'un gaz selon la revendication 1, caractérisé en ce que ladite pellicule déposée sur la matière d'étanchéité du détecteur ultrasonique est constituée par une pellicule (58) d'une matière non conductrice déposée sur la couche (51) de matière d'étanchéité et par une pellicule (57) d'une matière conductrice déposée sur ladite pellicule (58) de matière non conductrice (Fig. 7).

3. Un instrument pour mesurer la concentration d'un gaz selon la revendication 2, caractérisé en ce que ledit détecteur ultrasonique est noyé dans un bloc (67) définissant un espace intérieur qui contient ledit détecteur ultrasonique, des matières élastiques d'étanchéité (74, 75) prévues dans des espaces d'air entre le bloc (67) et les surfaces latérales du détecteur pour fixer en place le détecteur ultrasonique, et au moins l'une d'une pellicule (78) en une matière électriquement non conductrice et d'une pellicule (79) en une matière électriquement conductrice formée par la méthode d'évaporation, de pulvérisation ou de placage ionique de manière à couvrir une face extrême vibrante (71) du détecteur ultrasonique, une surface extrême (72) du bloc et une surface de la matière élastique d'étanchéité (Fig. 9).

FIG. 1

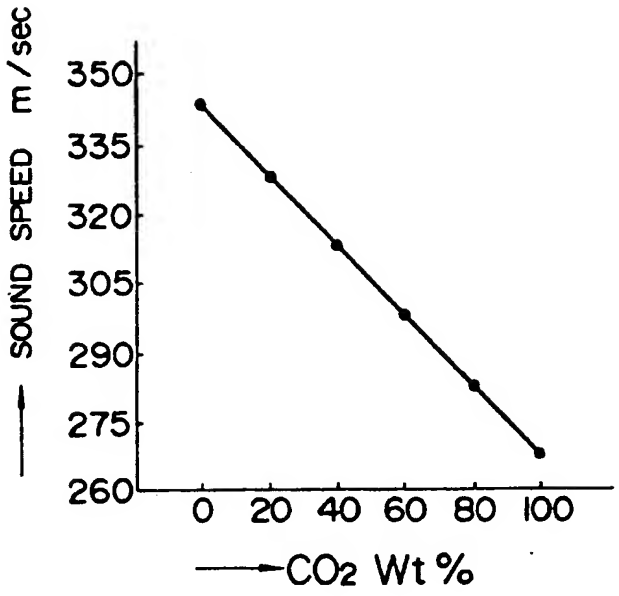
SOUND SPEED m/sec
350
335
320
305
290
275
260
0
20
40
60
80
100
CO2 Wt %

FIG. 2

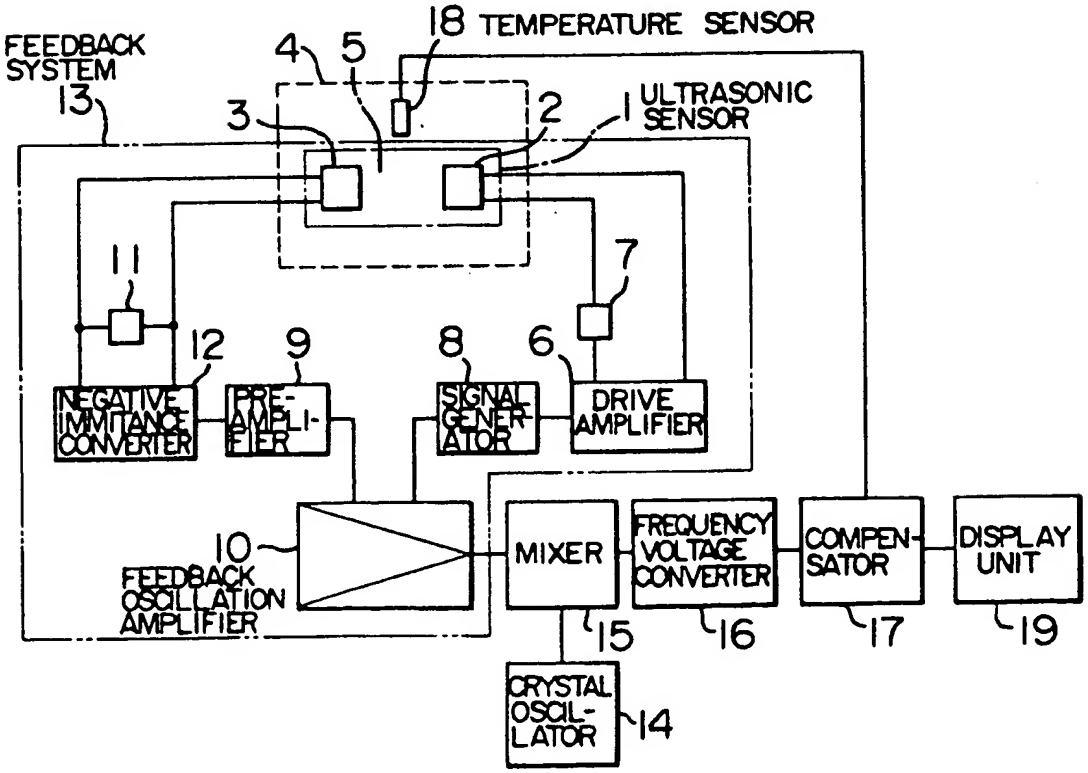
FEEDBACK SYSTEM
13
18 TEMPERATURE SENSOR
4
5
3
2
1 ULTRASONIC SENSOR
11
7
12
9
8
6
NEGATIVE IMMITANCE CONVERTER
PRE-AMPLI-FIER
SIGNAL GENER-ATOR
DRIVE AMPLIFIER
10
FEEDBACK OSCILLATION AMPLIFIER
MIXER
FREQUENCY VOLTAGE CONVERTER
COMPEN-SATOR
DISPLAY UNIT
15
16
17
19
CRYSTAL OSCIL-LATOR
14

FIG. 3

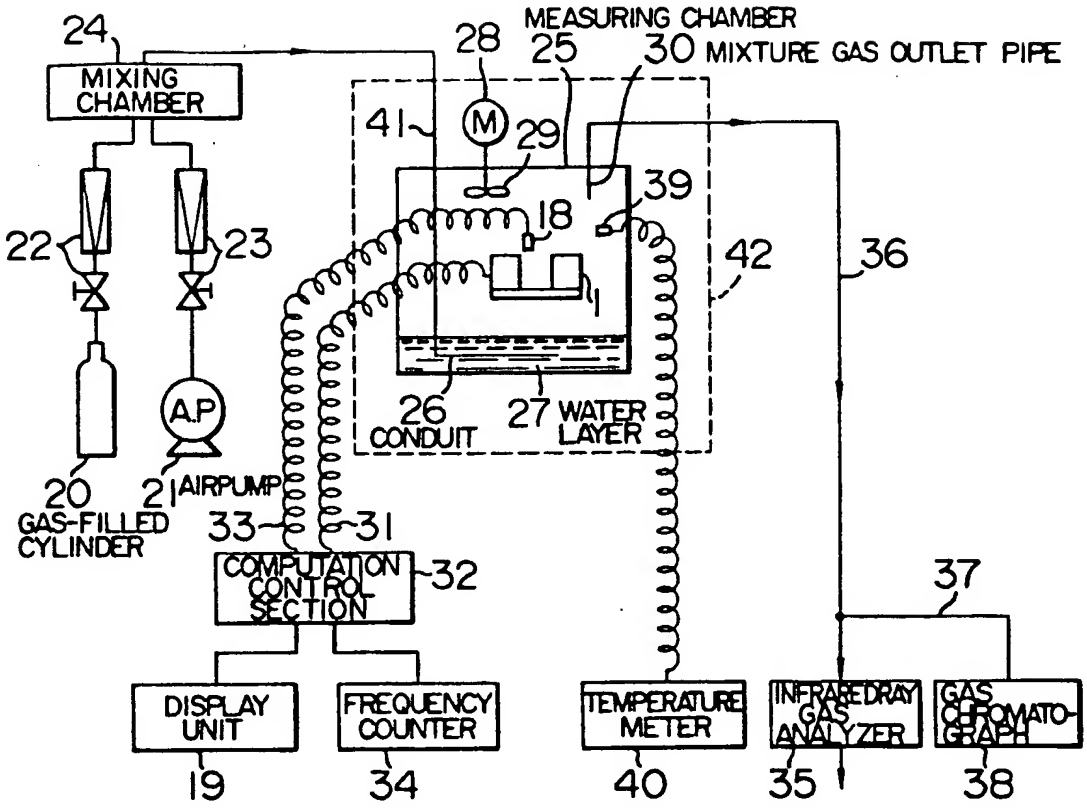
24
MIXING CHAMBER
28
25
MEASURING CHAMBER
30
MIXTURE GAS OUTLET PIPE
41
M
29
39
18
22
23
42
36
A.P
26
CONDUIT
27
WATER LAYER
20
GAS-FILLED CYLINDER
21
AIRPUMP
33
31
COMPUTATION CONTROL SECTION
32
37
DISPLAY UNIT
FREQUENCY COUNTER
TEMPERATURE METER
INFRARED GAS ANALYZER
GAS CHROMATO-GRAPH
19
34
40
35
38

FIG. 4

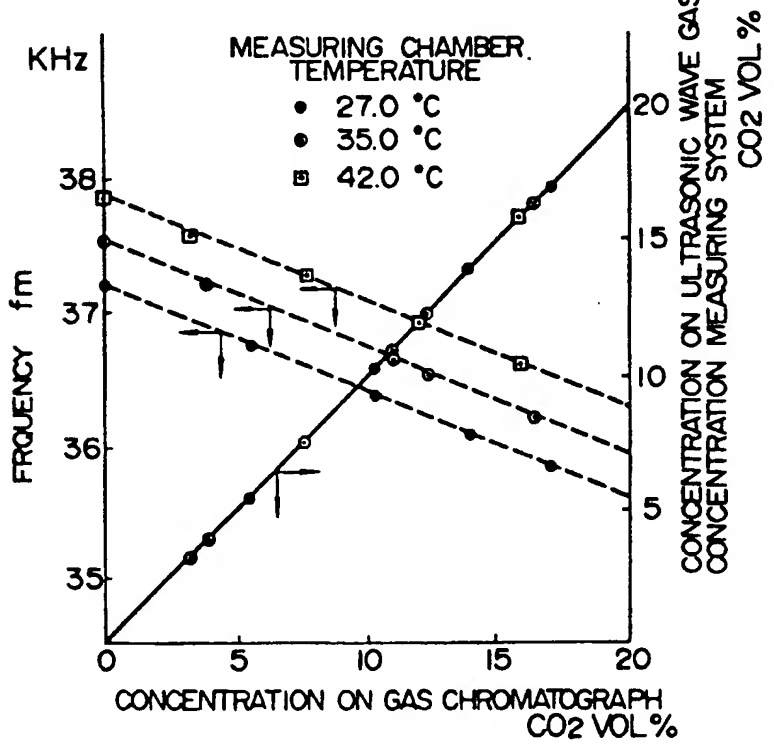
KHz
MEASURING CHAMBER TEMPERATURE
27.0 °C
35.0 °C
42.0 °C
38
37
36
35
FRQUENCY fm
0
5
10
15
20
CONCENTRATION ON GAS CHROMATOGRAPH CO2 VOL %
CONCENTRATION ON ULTRASONIC WAVE GAS CONCENTRATION MEASURING SYSTEM CO2 VOL %

FIG. 5

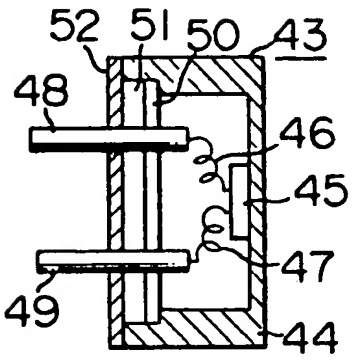

FIG. 6

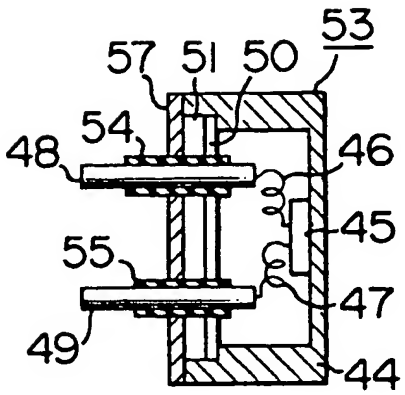

FIG. 7

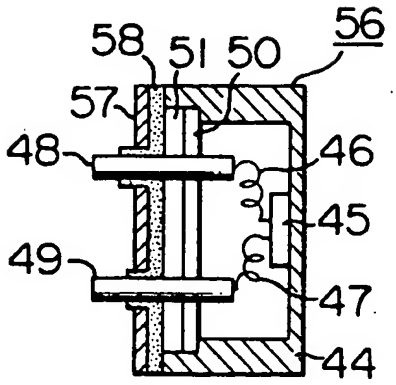

FIG. 8a

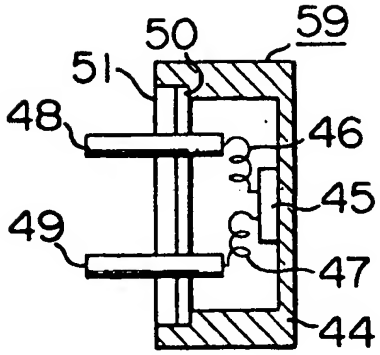

FIG. 8b

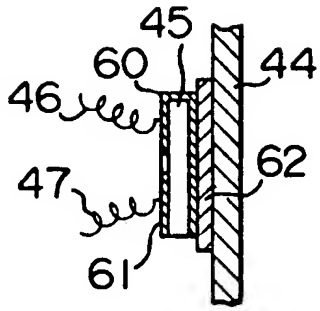

FIG. 9

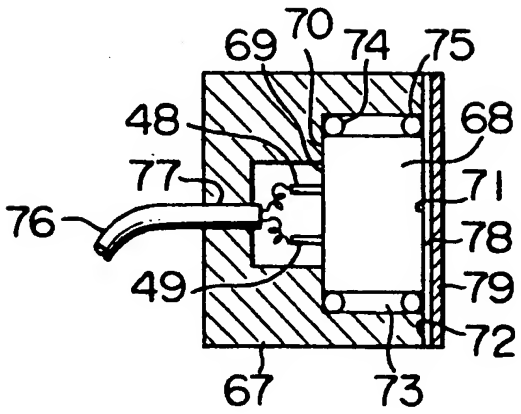
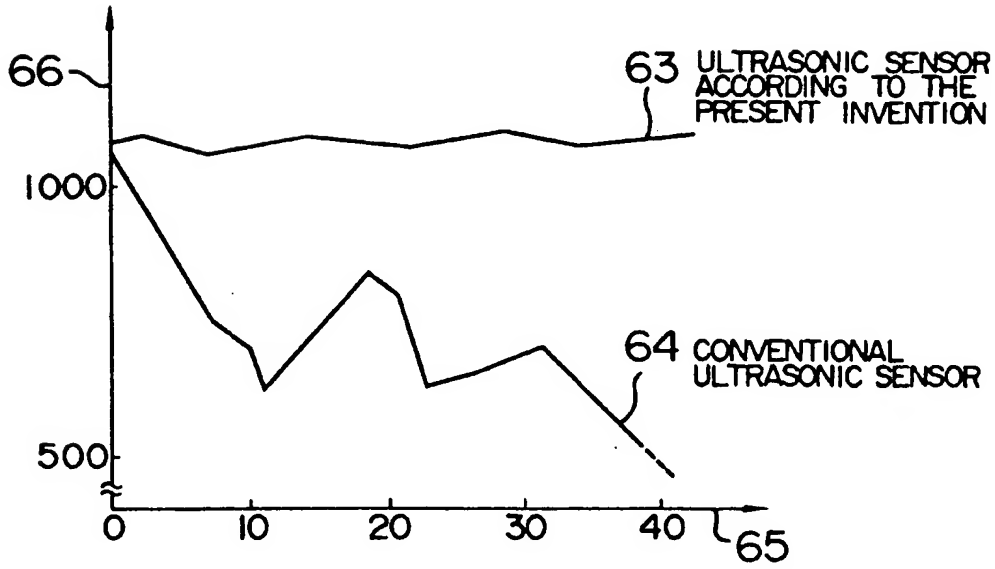
FIG. 10